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- *Title:* Technology Showcase: Integrated Monitoring, Diagnostics and Failure Prevention. Proceedings of a Joint Conference, Mobile, Alabama, April 22-26, 1996.

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THE MINI-LAB CONCEPT AS AN

ALTERNATIVE TO

CONVENTIONAL OIL ANALYSIS

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ABSTRACT

Analysis of used oil has proven itself to be a useful condition monitoring technique for mechanical equipment. Traditional oil analysis involves taking an oil sample and sending it away to a remote laboratory for analysis. This has many short comings such as lack of ownership of the program and long lead times for recovering results. Until recently installing lubricant analysis capabilities on site have been precluded as instrumentation has been cost prohibitive. However recent developments in both instrumentation and intelligent software allows successful and cost effective implementation of on site lubricant analysis capabilities.

Key Words: On site analysis, Mini lab, Lubricant testing, maintenance, condition monitoring.

1.0 INTRODUCTION

Lubricant analysis has been around as a maintenance tool for a number of years. Most plants know of it's availability and a number are using it in some form with varying success. However there has not been the general acceptance of the technology in industry as the has for example monitoring process control parameters. This is due to :

- The lube analysis business has been dominated by laboratories analysing internal combustion engines. This has led to industrial plant with complex and differing deterioration mechanisms being treated like "diesel engines" providing end users with limited success in industrial applications. Lubricant analysis in industrial applications has defaulted itself as a detection technology whereas end users require detailed knowledge of failure process and how to address these from a root cause perspective.

- One of the chief obstacles in achieving general acceptance of lubricant analysis as a valid technology for industrial plant is so called ***free oil analysis*** where the market place has forced lubricant vendors to provide such a service. Generally free oil analysis is characterised by very limited spectrometric analysis with limited diagnostic capabilities, which might be a totally inappropriate technology for say a steel rolling mill.

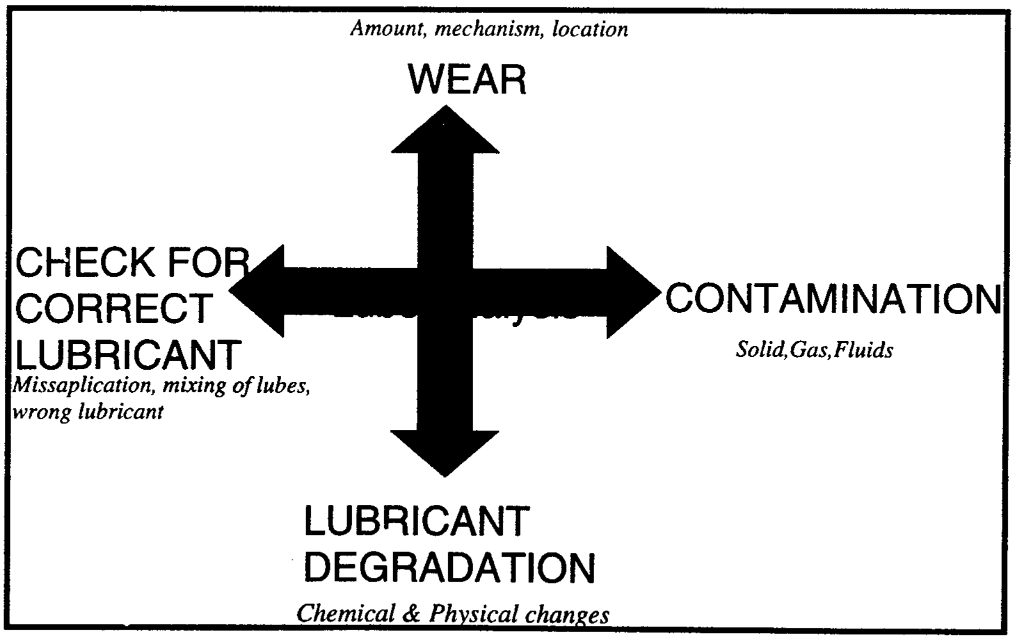
- There is often a disconnect between a plant and the laboratory analysing the sample. This is born out by frustration with turnaround times for results, lab diagnosticians poor awareness of industrial equipment, and a general break down of communication between what maintenance people require to make decisions and what lubricant analysis reports contain.

This paper argues that there is an opportunity of overcoming these frustrations and making real benefit from the technology by installing On Site Lube Analysis tools referred to as the Mini- Lab.

2.0 OVERVIEW OF LUBE ANALYSIS TECHNOLOGY

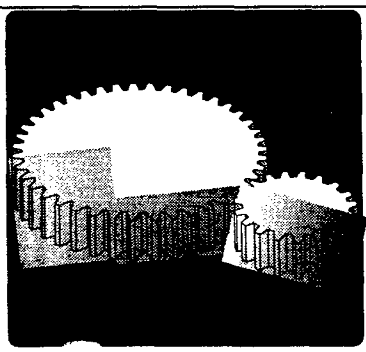
One conducts lubricant analysis for four reasons:

- To monitor mechanical surface damage (wear) of Componentry within a system.
- To check for both solid, fluid and gas contamination.
- To check for degradation (loss of function) within the lubricant.
- To check that the correctly specified lubricant is within the system.



2.1 Lube Analysis In Industrial Plants

There is a large variety of complex systems operating in industrial plants. In order to move beyond a simple fault detection approach and provide a more comprehensive understanding of the dynamics within such systems one has to adopt a more sophisticated approach which utilises the full capabilities of modern lube analysis technology. This means understanding the operational dynamics within a system together with the failure modes and matching these to applicable tests which will detect and diagnose these conditions. In order to accomplish this objective I would like to introduce the concept of a Lubricant Analysis Profile. Which is essentially a collection of tests appropriate to specific systems. (Lets get away from treating everything as a diesel engine). Below I illustrate the selection of two typical profiles, one for a gearbox, and another for a hydraulic system.



Profile: Gearbox
Wear Debris Analysis
Viscometry 40 & 100 C, &VI
Spectro Metals (wear, additives, ontaminanats)
FTIR Spectroscopy
Total Acid Number
Water

Profile: Hydraulic System
Particle Count
Viscometry
Spectro Metals (additives)
FTIR Spectrometry
Total Acid Number
Water

Illustration of the use of Profiles
for two differing industrial applications

Gearbox	Hydraulic System
Need to monitor: • Mechanical wear, which is normally seen in particles larger than the range of detection for spectrometers. Anti wear, anti oxidant and anti scuff additive depletion • Oil oxidation • Acid build up. • Water and other contaminants	Need to monitor • Solid contaminants by particle count • Water • Depletion of anti wear additive • Oil oxidation • Acid build up • Wear

Monitoring Objectives for a gearbox profile
compared to a hydraulic system

For example a gearbox in a large mechanical drive will require a differing set of tests (referred to as the monitoring profile) to that of a turbine in a nuclear power station. It is therefore important for the condition monitoring practitioner to understand the differing damage and deterioration mechanisms that occur within a particular system so as to allocate the correct profile in order to optimally benefit from a condition monitoring program.

In order to understand how to set up Profiles lets us review the various capabilities of lube analysis technology.:

1. **Spectro Metals Analysis** providing elemental analysis (Fe, Cr, Zn, Si etc.) gives information on:
   - Wear Metals
   - Metallo Organic Additives
   - Contaminants

2. **Viscometry** indicates firstly whether one is using the correct grade of lubricant and secondly viscosity increases or decreases measure certain physical effects on the lubricant. Viscosity is an extremely important parameter to measure as it determines the thickness of the fluid film.

3. **FTIR Molecular Spectrometry** (Fourier Transform Infrared Spectrometry) measures the degradation of functionality within the lubricant.

4. **Wear Debris Analysis** (Ferrography) measures the extent, location and mechanisms of wear.

5. **Particle Counting** measures solid contamination within a system.

6. **TAN** (Total Acid Number), **TBN** (Total Base Number) measures acid build up, and reserve alkalinity depletion.

Technology	Capabilities	Comments
Spectro Metals Analysis	Wear Metals Metallo-Organic Additives Contaminants	Severe Particle Size limitations
FTIR Spectrometry	Lubricant Degradation Fluid Contamination (water) Good for QA & QC of lubricants	Becoming increasingly used as the technology of choice, As FTIR systems and associated data management systems improve.
Wear Debris Analysis	Diagnostic tool for wear related system deterioration. No particle size limitation. Excellent tool for root cause analysis	Limited proactive capability, mainly a diagnostic tool
Particle Counting	Measures solid contamination. Lead technology for monitoring clean oil systems.	Measurement technologies, lack absolute precision.
Viscometry	Good indicator of fluid integrity. Can measure lubricant degradation or misapplication.	

Summary table indicating the principle lab based fluid analysis technologies

3.0 THE MINI-LAB CONCEPT

This paper argues that as more emphasis is being placed on industrial productivity and the associated need to maximize machinery uptime, so the importance of the role that qualified maintenance decisions have in ensuring optimum plant availability. The quality of this decision making is going to be based on the availability of good reliable information. *This premise defines the role of the Mini-Lab.* It is the direct on site evaluation tool for system and lubricant evaluation whose purpose is to continuously supply current information in a form to enable such maintenance decision making.

What Can Be Measured On site?

Instrument	Capabilities	Comment
Oilview Analyzer 5100	Wear Ferrous Non Ferrous Wear Lube degradation Contamination	Sensitivity to 1 ppm Sensitivity to 100 ppm Excellent field tool for measuring oil degradation in the field. Good indicator of water. Can measure water in solution, dispersion and emmisable water.
Oilview Ferrous Wear Monitor	Measures amount of paramagnetic iron within the sample.	No particle size limitations, simple to use, excellent screening tool
Digital Viscometer	Measures absolute viscosity in the field.	Simple to use field test for viscosity. Verify correct lube. Detect fuel dilution.
Oilview Particle Counter	Absolute measure of solid contamination.	Has additional sensors that measure absolute colour and dielectric of the oil, giving indication of oil condition.
Wear Debris Analysis (ferrography)	From microscopic examination of the wear particles, determine the nature, extent and mechanism of wear	Excellent diagnostic tool, as it uniquely provides information on the mechanism of wear.

Summary table indicating instrument capabilities

3.1 Wear:

Wear is the primary mechanism by which industrial plant deteriorates, By observing the amount and mechanism of wear periodically one is able to monitor the deterioration of plant. Traditionally this has been done by SOAP Analysis (spectrometric oil analytical procedure).

As apposed to SOAP which is a chemical based analytical technique, there are a number of new instruments which are able to accurately measure wear on site. Typical field instruments that ,measure wear are the CSI Oilview Ferrous Wear Monitor 51 FW and the Oilview Analyzer 5100, the Tribometrics and the Analex PQ90.

3.1.1 Oilview Ferrous Wear Monitor. 51FW

The Oilview 51FW measures the effect that an oil sample has on a magnetic field. In other words it gives a direct indication of the amount of Ferrous Wear within a sample. Operation is simple and involves no measurement of sample volumes or dilution. The sample bottle is simply set on the top of the Monitor which immediately gives an indication of the amount of paramagnetic ferrous debris within the sample. The assumption being that ferrous wear will give a significant indication of system deterioration. This is principally valid for industrial power transmission systems such as large gearboxes and heavy loaded rolling element bearings.

3.1.2 Oilview Analyzer 5100

The Oilview Analyzer 5100 s able to measure both Ferrous and Non-Ferrous wear. The sensitivity to Ferrous Wear has been determined to be very accurate in the range of 1ppm Iron and non ferrous wear less accurately to around 100ppm. The Analyzer uses a combination of measuring the electrical properties of the oil, the magnetic properties of the debris and the time based settling of suspended debris due to gravity. The combination of measurement technologies within the instrument allows not only determination of wear, but a measure of contaminants such as water (very accurately), and most significantly a field based indication of lubricant deterioration. The measure of lubricant deterioration is achieved by a comparison of the dielectric properties of a new oil which is stored in a database, as compared with the sample of oil which has been drawn from an operating system. Not only can this condition parameter give an indication of field degradation of the lubricant, it can be used as a quality control tool for the testing of variations within supply of new lubricants.

3.1.3 Wear Debris Analysis

Wear Debris Analysis is a physical technique which quantifies and characterises the amount of wear within a system. There are a limited number of wear mechanisms, each of which generates wear particles with a distinct morphological appearance. One can periodically sample, quantify and observe these wear particles in order to understand the extent and mechanism of wear within systems. Interpretation of the results from this process gives direct information on the type location and extent of damage within a system.

This has powerful and far ranging implications, for instead of being simply satisfied with a detection capability of measuring too much wear, one can now move into a diagnostic mode where the mechanism is identified, together with the extent of damage. This allows a more meaningful conclusion as to the level of threat that a particular system is operating under.

An additional important consideration where Wear Debris Analysis has significant advantages over SOAP techniques is that it does not suffer from the ever present problem of particle size limitations. Spectrometers used in oil analysis today have a restriction in that they do not measure particles over 8 microns in size. In power transmissions this is a major problem as the majority of damage mechanisms (not all) generate particles greater than 8 microns. In addition a general rule is that as damage progresses these particles increase in size. SOAP analysis has failed to provide information on these situations, much to many end users frustrations. Wear Debris analysis has no such limitation, and besides being able to quantify the amount of wear, gives valuable information on mechanism, location, and extent of wear as well as the state of the lubricant and presence of contaminants.

Wear Debris Analysis or Ferrography has been presented has a high powered complex technology, where in essence it is the separation and measurement of wear particle characteristics under a suitable microscope. Even a limited capability for undertaking visual particle examination on site provides great insights into what is happening within a system. The viewing of the wear particles provides a direct understanding of damage modes and extents within systems. With a degree of training and experience, wear debris analysis becomes a powerful on site analysis tool especially appropriate in industrial power transmission systems.

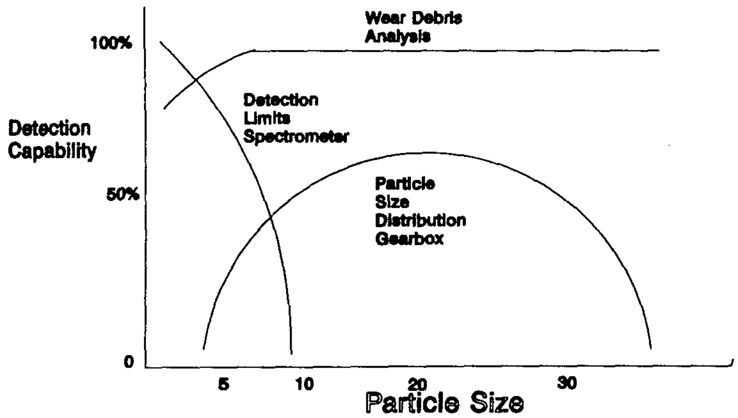


Fig. 2 Showing the particles size effects of SOAP vs. Wear Debris analysis.

3.2 Viscometry

The viscosity of a lubricant is the essential lubricating property of the fluid. It not only determines the lubrication regime but will also define essential lubrication conditions such as the fluid film thickness. Variations in viscosity are an indication of fluid degradation, or contamination, or just as meaningful, give the best indication of misapplication of a lubricant. A jump in viscosity from 220 Cst in a gear system to 100 Cst probably means that an incorrect lubricant has been applied to the system.

3.5 Contamination Control Through Particle Counting

Solid contamination especially in clean oil systems is the single most important contributor to wear, the primary root cause of failure. It is therefore simple common sense to maintain determined cleanliness levels within sensitive systems. Proactive contamination control has is becoming more and more well accepted as general engineering practise and consists of five essential principles. These are defined as:

Contamination Analysis the measurement and understanding of the amount type and composition of contaminants.

Contaminant Exclusion the identification and minimising of contaminant sources.

Contaminant Removal the practices and procedures for removing contaminant that can not be excluded, such as , residual manufacturing debris or generated contaminant within a fluid system.

Contaminant Tolerance ensuring that components can tolerate (not degrade performance beyond allowable limits) the level of contaminant that is not excluded or removed.

Systems Approach establishing a systematic approach that ensures that the system Target Cleanliness Level (TCL) is achieved and maintained.

A proactive contamination control program is not a condition monitoring program where one is trying to detect unhealthy conditions. Essentially one is dealing with a root cause which initiates ill health within machinery, thereby eliminating initiation of the failure cycle. This provides enormous benefits in terms of reliability and life extension such as indicated in the BHRA published results shown below.

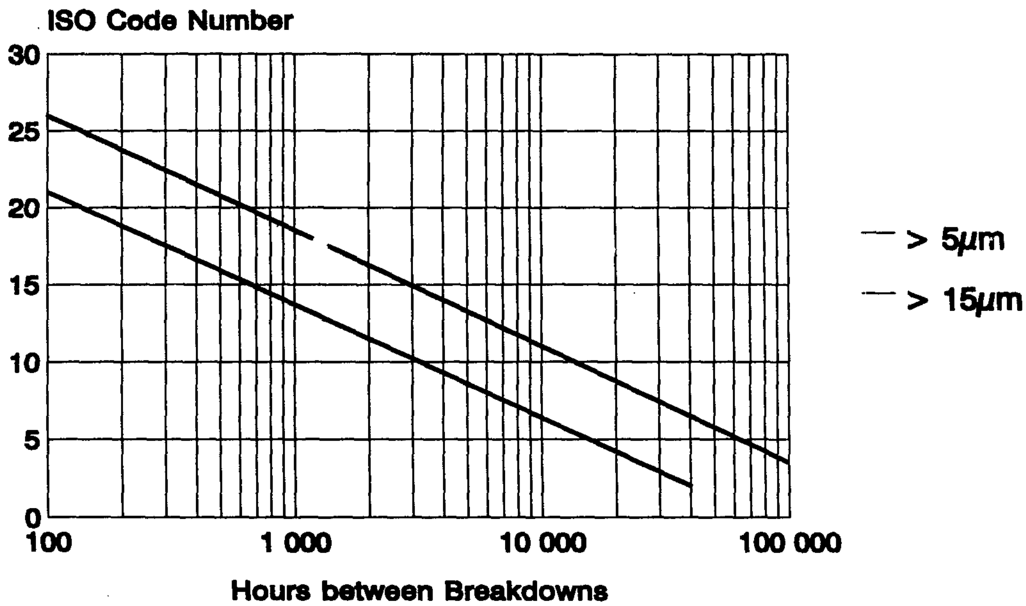


Fig. 1 BHRA Study of Effect of Cleanliness on Life Extension of Hydraulic Pumps

A proactive contamination control program by it's nature involves extensive testing. Relying on a remote laboratory is firstly to time consuming and secondly will result in testing costs mounting. Having an accurate particle counting capability on site as part of the testing capability provides an effective solution.

The Oilview Particle Counter 51PC is a state of the art laser based particle counter with the highest degree of accuracy which is important in contamination control. In addition it has two additional sensors that measure the fluid condition, these are a sensor that measures the electrical properties and the fluid colour. This allows information on solid contamination and fluid condition in a single pass.

3.6 Mini Lab Profiles

Similar to the concept of using Profiles for effective industrial lubricant analysis, the mini lab can be configured in terms of what would be most effective in monitoring the range of systems operating within a plant.

For example a precision machining shop would be running predominantly clean systems which require a "proactive approach". The Mini Lab Profile which would be configured for this application is as follows:

Instrument	Capability
Particle Counter 51PC	Accurate measure of solid contaminants, together with indication of lubricant condition.
Analyzer 5100	Measures, water contamination and lubricant degradation
Digital Viscometer 51DV	Verify viscosity changes and use of correct lubricant.

Minilab Clean System Profile

For comparison a Mini Lab profile for an Industrial Site which predominantly monitored gear trains would have an instrumentation profile as follows:

Instrument	Capability
Ferrous Wear Monitor	Detection of Ferrous wear.
Analyzer 5100	Detection of ferrous and non ferrous wear, together with water contamination and lubricant degradation
Wear Debris Analysis (Ferrography)	Detailed examination of particles in order to understand nature, mechanism and extent of wear.
Digital Viscometer 51DV	Verify viscosity changes and use of correct lubricant.

Minilab Industrial System Profile

4.0 DOES THE FLUID ANALYSIS LABORATORY STILL HAVE A ROLE ?

The concept of the Mini-Lab is specifically designed to be able to be simply operated by maintenance practitioners (as apposed to chemists) to provide simple detection and diagnosis capabilities on-site (in the plant work environment).

The fluid analysis laboratory (where the chemists work) has an integral role in this scenario by providing advanced back up to the mini lab on an as needed basis. In order for the fluid analysis lab to be able to do this it has to redefine it's purpose from that of handling large volumes of samples efficiently to keep costs down, to being the detailed diagnostic backstop with all the associated expertise and capabilities for the Mini-Lab contributing meaningful solutions to real problems. (No more diagnosing gearbox problems, with an engine analysis mind set)

An example of this relationship is indicated as follows: A Mini-Lab at a plant detects a contamination problem in a high speed compressor. The condition is detected on site using the particle counter. The role and function of the Fluid Analysis Laboratory would at this point be to identify the exact nature of the contaminant, define the threat that it poses to the specific componentry within the system and then make recommendations as to a set of activities which will address the source of the contaminant together with the Tribological management strategy to contain the situation, by addressing the root cause. This may be far removed from existing practises within lubricant analysis laboratories at this point in time. However what is achieved is an effective solution, rather than a symptomatic evaluation. It is up to users of oil analysis services to force this as a competitive aspect of purchasing such services. This will provide a realistic and meaningful solution to those plants serious about their condition monitoring programs.

5.0 SUMMARY OF BENEFITS OF ON SITE LUBRICANT ANALYSIS CAPABILITIES.

Setting up in house on site capabilities for the routine analysis of lubricants has many advantages over contracting out oil analysis. A summary of these is as follows:

- The end user has total ownership of the program. Success or failures is determined by a defined effort, with no external influence.
- There is immediate access to results, no waiting for external lab turnaround. In addition samples don't go "*missing*".
- There is ownership of the test process together with the results. With this site specific expertise around the plants own machines can be built up.
- One can set up appropriate test profiles per compartment.
- Over time costs are significantly reduced. In addition sampling and testing frequencies are now not cost constrained. (you can test us much as you want with no increased cost consideration)
- When a problem is tested, one can immediately resample, and much more closely manage the situation. One can sample daily, hourly etc. with immediate access to the results.
- There is a relatively low skills requirement to set up, and run such a program.
- An on site facility can easily be integrated into existing programs such as vibration, thermal imaging etc.
- One can electronically link into an external testing lab where samples requiring additional testing can be routed.

6.0 SOME ADDITIONAL SIDE BENEFITS OF HAVING A MINI LAB ON SITE

Beyond the main concern to prevent unexpected failures and machine life extension which most users of such systems have, there are a number of side benefits that have been experienced. These side benefits are easily overlooked but all contribute to instigating better use of machinery and reducing the running costs for users. Some of the hidden benefits which have been experienced are:

° regular sampling ensures that there is lubricant in the system
° the oil is in a state whereby it will serve the required function
° reduction or elimination of unexpected failures allows better use of manpower
° regular monitoring of mature machines, where redundancy was considered has allowed considerable life extension.
° allowing slightly degraded machines to be run until they can be conveniently rectified, whereas previously this machine may have been immediately taken out of service with resultant loss of availability.
° due to the reduction in failures, the high costs of transport, storage and handling of spares and sub assemblies is greatly reduced. In the mining industry this figure is estimated to be as high as 22% of the life cycle costs of machines
° by sampling a unit immediately prior or after entering service an indication of the quality and workmanship during maintenance is obtained. At one site this has led to an improved standard of maintenance both internally and by external contractors.

7.0 CONCLUSIONS

Several methods exist for the monitoring of machine health. Present experience indicates the simple method of extracting oil samples periodically and monitoring the rate of wear, together with measuring contamination and fluid degradation are particularly appropriate to industrial applications. The ability to conduct testing on site is shown to be both a relatively simple and cost effective option, together with providing a number of benefits which would not have accrued by contracting the samples to a Lube analysis laboratory.

A set of instrumentation has been described which is both simple to use and measures the primary deterioration mechanisms within industrial systems. These instruments make up what is known as the Mini-Lab. The role of the Mini-Lab is one of problem identification (detection) with limited diagnosis, where it is suggested that the role and function of the advanced fluids analysis lab has a role of more advanced problem definition and diagnosis. This combined with the capability of providing recommendations as to eliminating the root cause of the problem.

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